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N. Takamaru, and I. Sato

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Predation of Bivalves by Sea Stars, with Special Reference to the Predation of *Pseudocardium sybillae* and *Mactra chinensis* by *Luidea yesoensis*

by Noriyoshi TAKAMARU (Kushiro Fisheries Experimental Station)
and Ichio SATO (Notsuke Fishermen's Cooperative Association)

Sea stars are generally carnivorous, and are known to be predators of bivalves in particular[1) ~ 6)], they cause considerable damage to fishing grounds for useful bivalves[7)], and are a factor causing large decreases in the numbers of seed *Anadara broughtonii* and *Patinopecten yesoensis* immediately after their release[8)9)]. Therefore, in order to shed light on the movement of bivalve populations, it is necessary to determine the quantities eaten by sea stars. In addition, when creating fishing grounds for useful bivalves or releasing seeds, one should first have an understanding of the distribution and predatory behaviour of sea stars in the sea area concerned.

This time, the distribution and the stomach contents of sea stars were observed along the shore of Notsuke Peninsula at Bekkai-chō and on the Ryūjin Bank, which are fishing grounds for Pseudocardium sybillae and Mactra chinensis, and greater understanding of the predation of P. sybillae and M. chinensis by Luidea yesoensis in particular was obtained.

Before proceeding with this report, the authors would like to express their gratitude to persons connected with the Notsuke Fishermen's Cooperative Association, the Nemuro North Guidance Centre for the Dissemination of Fisheries Technology, and the Bekkai-chō Fisheries Section who cooperated in this survey.

Survey Methods

The sea areas surveyed were the area along the shore of Notsuke Peninsula in the central part of the Nemuro Strait and the vicinity of the Ryūjin Bank, 2 to 5 m deep, situated to the southeast of it (Fig. 1). This sea area is a fishing ground for P. sybillae and M. chinensis with a depth of 5 m and a substrate of fine sand.

The sea stars were collected on November 10, 1981 by means of a dredge net (width of beam 2 m, mesh 6 cm) for the extermination of sea stars - modified from a P. yesoensis dredge net - which was towed 250 m parallel to the shoreline in the Notsuke Peninsula fishing ground (st. 1 to 17) and in an east-west direction in the Ryūjin Bank fishing ground (st. 18 to 25). The sea stars collected were sorted by species and counted, and for some of the specimens the length of the arms, the wet weight and the contents of the stomach were determined. In the case of L. yesoensis in particular, 20 individuals collected at each

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point were fixed in 10% Formalin and brought to the laboratory, where the stomach contents were observed. The stomach contents were sorted by species and counted, and for P. sybillae and M. chinensis the shell length was measured by means of a sliding caliper.

In addition, in order to determine the distribution of juvenile P. sybillae and juvenile M. chinensis at the time of this survey, samples of the substrate were obtained by means of a Smith-McIntyre bottom sampler (collection area: 0.05 m^2), and the P. sybillae and M. chinensis were separated from the substrate by means of a 1 mm mesh sieve. These were collected, and the shell length of the P. sybillae and the M. chinensis was measured by the above-mentioned method.

Results

1. Distribution of Sea Stars

The sea stars collected during this survey belonged to the following seven species: Asterias amurensis, Distolasterias nippon, Lysatrosoma anthostictha, Luidea yesoensis, Certonardoa semiregularis, p. 129 Asterina pectinifera and Solaster borealis.

The densities and the percentages accounted for by the various species of sea stars in the Notsuke Peninsula fishing ground and the Ryūjin Bank fishing ground are shown in Table 1. The density of the sea stars was 0.397 individuals/m^2 in the Notsuke Peninsula fishing ground and 0.168 individuals/m^2 in the Ryūjin Bank fishing ground. In both fishing grounds the density of A. amurensis and L. yesoensis was high, and that of D. nippon and A. pectinifera was low. The other three species of sea stars were excluded from this table because their combined density was less than 0.001 individual/m^2. With regard to

the percentages accounted for by the various species of sea stars in the Notsuke Peninsula and Ryūjin Bank fishing grounds, A. amurensis constituted 59.9% and 65.4% respectively, and L. yesoensis 34.3% and 31.0%. These two species accounted for more than 90% of the total. D. nippon constituted 3.0% and 1.8% respectively, and A. pectinifera 2.8% and 1.8%.

Fig. 2 shows the distribution of sea stars. Sea stars were found over the entire sea area surveyed, and at many of the survey points there were 0.1 to 0.3 individuals/m^2, but there was a high-density area with more than 0.3 individuals/m^2 to the east of the Notsuke Peninsula fishing ground. At the centre of the Ryūjin Bank the density was less than 0.1 individual/m^2. The density of L. yesoensis was 0.1 to 0.3 individuals/m^2 on the western side of the Notsuke Peninsula fishing ground and on the southwestern side of the Ryūjin Bank fishing ground, in the area between the two fishing grounds it was less than 0.1 individual/m^2, and on the eastern side of the Ryūjin Bank fishing ground, no individuals were collected. The density of D. nippon and A. pectinifera was low - less than 0.1 individual/m^2 - but these species were widely distributed over the sea area surveyed, with the exception of the eastern side of the Ryūjin Bank. Because the numbers of individuals collected of the other species of sea stars were small, they are not shown in the table, and only one individual S. borealis each at st. 10 and st. 13 and one individual each of L. anthostictha and C. semiregularis at st. 10 were collected.

Fig. 3 shows the breakdown by arm length of the principal species of sea stars. The arm length of individual A. amurensis observed varied between 20 mm and 200 mm, and individuals with an arm length in the vicinity of 50 mm to 70 mm constituted a fairly high

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percentage. The breakdown by arm length of L. yesoensis shows a single mode centring around 60 to 70 mm. Two groups of D. nippon were observed, centring around 50 mm and 70 mm arm lengths. In the case of A. pectinifera, the percentage of individuals with an arm length of 40 mm was high.

2. Stomach Contents of Sea Stars

The stomach contents of sea stars observed this time are shown in Table 2. The number of individuals observed and the percentage of those accounted for by individuals with an empty stomach was 142 and 86.6% in the case of A. amurensis, 27 and 70.3% in the case of D. nippon, 463 and 14.8% in the case of L. yesoensis, and 23 and 73.9% in the case of A. pectinifera. In the case of L. yesoensis, the percentage of individuals in which food was found in the stomach was high. In the other species of sea stars, individuals with an empty stomach accounted for a high percentage - over 70%. In the case of A. amurensis, D. nippon and A. pectinifera, the number of shiomushi* that had been eaten was fairly large, and more than 0.6 shiomushi had been eaten per sea star. The L. yesoensis had eaten large numbers of bivalves; 9.6 bivalves had been eaten per individual L. yesoensis. In particular, the number of individual P. sybillae and M. chinensis that had been eaten was very large, 4.7 individuals [per sea star] in each case.

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*Translator's note: Transliteration of Japanese name. Search for Latin name unsuccessful.

Fig. 4 shows the percentage of individuals of the L. yesoensis population that had eaten P. sybillae and M. chinensis at the various survey points. P. sybillae had been eaten by 50 to 75% of L. yesoensis in the Notsuke Peninsula fishing ground and by over 80% of that species on the western side of the Ryūjin Bank fishing ground. In the case of M. chinensis, the percentage was low on the western side of the Notsuke Peninsula fishing ground and on the eastern side of the Ryūjin Bank fishing ground, but they had been eaten by 5 to 35% of L. yesoensis on the eastern side of the Notsuke Peninsula fishing ground and by over 80% of that species on the western side of the Ryūjin Bank fishing ground.

Fig. 5 shows the average number of individual P. sybillae and M. chinensis that had been eaten by L. yesoensis at each point. The number of individual P. sybillae eaten per individual L. yesoensis was small off the Notsuke Peninsula fishing ground, but between the Notsuke Peninsula fishing ground and the Ryūjin Bank fishing ground the number was 2.0 to 5.0, and on the western side of the Ryūjin Bank fishing ground the number was greater than 5. The number of individual M. chinensis eaten was less than 0.5 in the Notsuke Peninsula fishing ground, but in the Ryūjin Bank fishing ground the number was greater than 5.

3. Distribution of Juvenile P. sybillae and Juvenile M. chinensis

The distribution of juvenile P. sybillae and juvenile M. chinensis in this sea area was as shown in Fig. 6. With regard to juvenile P. sybillae, an average density of 52 individuals/m^2 was observed in the Notsuke Peninsula fishing ground, but in the area along

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the shore the density tended to be high. In the Ryūjin Bank fishing ground there were 26.6 individuals/m^2 on the western side, there were 90 individuals/m^2 in the central part, and none was observed on the eastern side. The distribution of juvenile M. chinensis was centred in the southwestern part of the Ryūjin Bank, and low-density distribution was observed off the Notsuke Peninsula fishing ground and on the eastern side of the Ryūjin Bank.

Fig. 7 shows the breakdown by shell length of P. sybillae and M. chinensis eaten by L. yesoensis and the breakdown by shell length of the juveniles of these two species in their natural habitat. The breakdown by shell length of P. sybillae observed in the stomach of L. yesoensis resembled the breakdown of the species in its natural habitat. Individuals with a shell length of 2 mm constituted a high percentage, and a small mode was observed also at 7 to 8 mm. In the case of M. chinensis as well, the breakdown by shell length of individuals found in the stomach of L. yesoensis resembled the breakdown for the natural population, and in both cases individuals with a shell length of 2 mm constituted a high percentage.

Discussion

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In the benthic animal communities in areas with sandy bottoms such as fishing grounds for P. sybillae, sea stars are situated at the apex of the food web, and not only are they directly predatory on benthic animals, they are also competitive with animals such as flatfish, which use benthic animals for food [2)10)]. The percentage of individuals with an empty stomach was high - over 70% - in the case of

A. amurensis, D. nippon and A. pectinifera among the four species of sea stars whose stomach contents were observed this time, but individuals in whose stomach food was found had principally eaten shiomushi, and small crustaceans and bivalves were found only in small quantities. When these species eat large animals, however, they project their stomach outside their body to cover the prey, which they digest and absorb. Because they do not take the prey into the body, it was impossible, by the observation this time of only the stomach contents, to account for all of the animals that had been eaten. In particular, it is known that A. amurensis, which appeared in the highest concentrations, dig up and eat bivalves buried in the sand[5)6)], and in order to estimate the quantities of P. sybillae and M. chinensis eaten in this sea area, further study based on the observation of phenomena such as this type of feeding behaviour will be necessary.

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On the other hand, because L. yesoensis ingest their food whole, the percentage of individuals with an empty stomach was low, 14.8%, and large quantities of food were observed in the stomach. Very large numbers of the food animals were juvenile P. sybillae and M. chinensis, and in addition to these two species, animals such as other bivalves, spiral-shelled molluscs, small crustaceans and polychaeta were observed in very small numbers. It is known that the animals eaten as food by the Luidea genus are principally echinoderms such as serpent's starfish[2)]. L. ciliaris is predatory on the sea stars Asterias rubens and A. glacialis[11)], L. clathrata is predatory on foraminifers and gastropods[12)], L. foliolata is predatory on serpent's starfish and scaphopods[2)], and on the sea cucumber Cucumaria lubrica

and the bivalve Protothaca staminea[13], and L. sarsi is predatory on the serpent's starfish Ophiura albida[14]. It is known that among species native to Japan, L. quinaria is predatory on serpent's starfish and polychaeta[15], but it is reported that L. yesoensis is predatory on shellfish[1)4)].

Of the stomach contents of L. yesoensis observed this time as well, bivalves constituted a high percentage, and with regard to echinoderms, only a small number of Scaphechinus griseus (Mortensen) were observed. The stomach contents were different from those found in other members of the genus Luidea.

It is clear that in the sea area surveyed this time the predatory behaviour of L. yesoensis is a factor in the decrease of P. sybillae and M. chinensis populations. Because the time required for the L. yesoensis to digest the bivalves is unclear, however, it is difficult to estimate the quantity of bivalves eaten by this species. It will be necessary to estimate the quantity of bivalves eaten on the basis of rearing experiments.

As described above, sea stars are predators of benthic animal populations in areas with sandy bottoms, and decreasing the quantity of this predation should also be a means of promoting the proliferation of useful benthic animals. For this purpose, not only capture by means of dredge nets but also the sprinkling of slaked lime[9)16)] and capture by means of traps[8)] are being contemplated. In addition, because seasonal p. 137
changes are observed in the feeding behaviour of sea stars, a method whereby bivalves would be released during periods when the feeding activity of sea stars is decreasing[17)] has been proposed. Because the

P. sybillae and M. chinensis eaten by the L. yesoensis observed this time were limited to small individuals, it is believed that the quantities of P. sybillae and M. chinensis eaten change as the animals grow. In order to study measures to prevent predation by sea stars, it is believed that these aspects of feeding behaviour and the quantities of bivalves eaten must be observed seasonally.

Summary

Observations were made of the actual distribution of sea stars and of their predation of bivalves along the shore of Notsuke Peninsula at Bekkai-chō and on the Ryūjin Bank.

1. The density of sea stars was 0.397 individuals/m^2 in the Notsuke Peninsula fishing ground, and 0.168 individuals/m^2 in the Ryūjin Bank fishing ground.

2. Seven species of sea stars inhabit this sea area. It was found that the two species Asterias amurensis and Luidea yesoensis constitute over 90% of the total number, and that Distolasterias nippon, Asterina pectinifera, Solaster borealis, Lysatrosoma anthostictha and Certonardoa semiregularis combined constitute less than 6%.

3. When the stomach contents of the sea stars were observed, it was found that large numbers of shiomushi had been eaten by A. amurensis, D. nippon and A. pectinifera, and that 0.6 shiomushi had been eaten per sea star. In the case of L. yesoensis, the quantities of juvenile P. sybillae and juvenile M. chinensis eaten were large, in each case 4.7 individuals per sea star.

4. In the Notsuke Peninsula fishing ground, 50 to 75% of the L. yesoensis population had eaten juvenile P. sybillae, and 5 to 35% had eaten juvenile M. chinensis. On the western side of the Ryūjin Bank fishing ground, over 80% had eaten juvenile P. sybillae and juvenile M. chinensis.

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(昭和58年3月12日受理)

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*Translator's note: The spellings of Japanese personal names given here indicate the probable readings of the names.

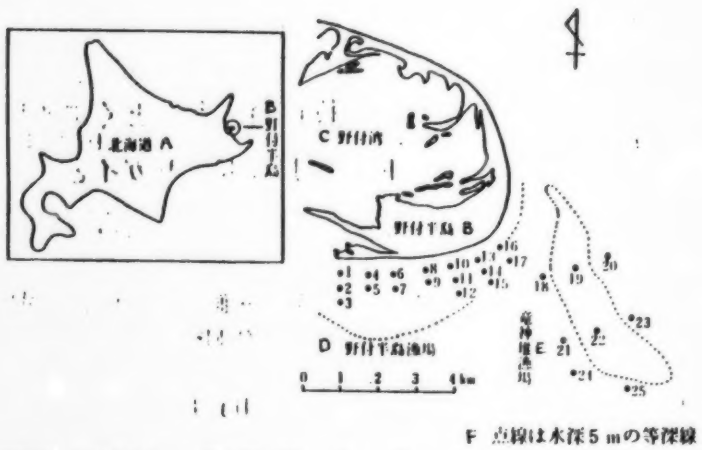
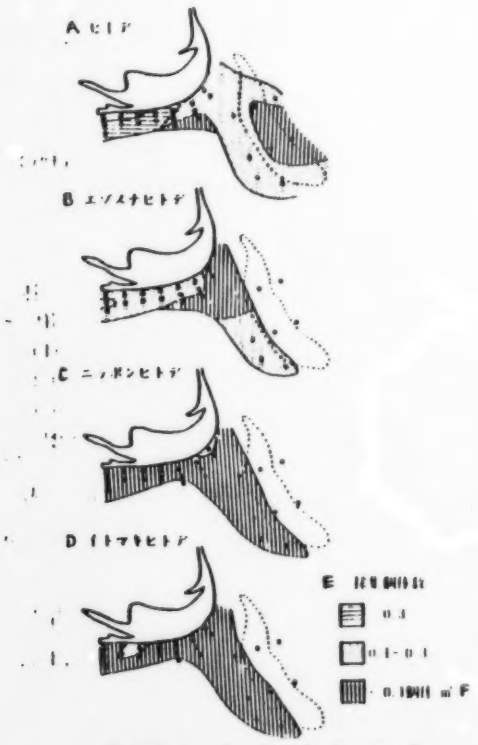


Fig. 1. Survey points 第1図 調 査 地 点

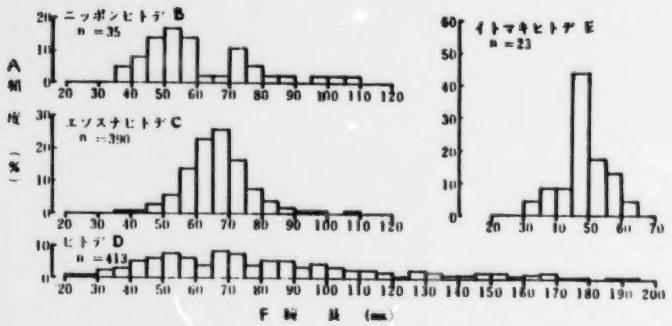
Key: A. Hokkaidō, B. Notsuke Peninsula, C. Notsuke Bay, D. Notsuke Peninsula fishing ground, E. Ryūjin Bank fishing ground, F. Dotted line is a contour line indicating a depth of 5 m.



第2図 ヒ ト デ 類 の 分 布

Fig. 2. Distribution of Sea Stars

Key: A. Asterias amurensis, B. Luidea yesoensis, C. Distolasterias nippon, D. Asterina pectinifera, E. Number of individuals collected, F. < 0.1 individual/m^2.

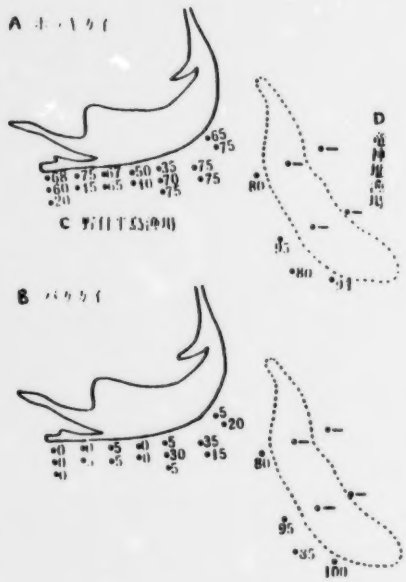


第3図 ヒトデ類の腕長組成

n＝測定個体数

Fig. 3: Breakdown by Arm Length of Sea Stars

Key: A. Frequency (%), B. Distolasterias nippon, C. Luidea yesoensis, D. Asterias amurensis, E. Asterina pectinifera, F. Arm length (mm), n. Number of individuals measured.

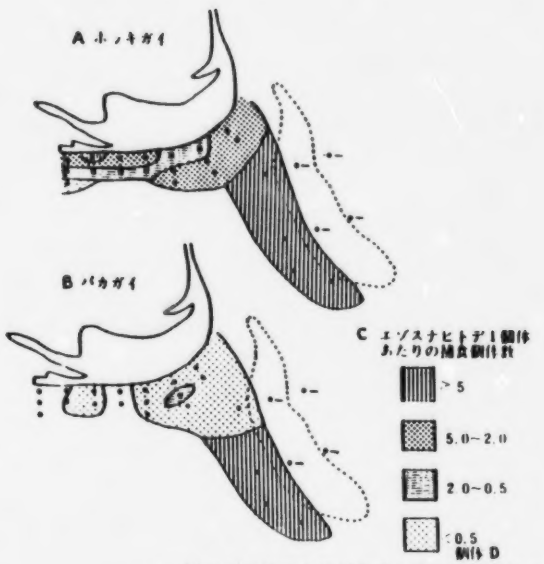


—はエゾスナヒトデが生息していない調査点

第4図 エゾスナヒトデ個体群中に占めるホッキガイとバカガイを捕食しているエゾスナヒトデの比率（%）

Fig. 4: Percentage of Total Luidea yesoensis Population That Had Eaten Pseudocardium sybillae and Mactra chinensis

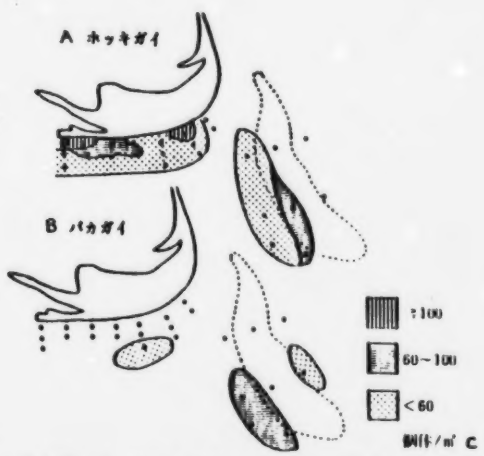
Key: A. Pseudocardium sybillae, B. Mactra chinensis, C. Notsuke Peninsula fishing ground, D. Ryūjin Bank fishing ground, – indicates a survey point at which Luidea yesoensis were not found.



第5図 エゾスナヒトデに捕食されているホッキガイとバカガイの個体数

Fig. 5: Numbers of Pseudocardium sybillae and Mactra chinensis Eaten by Luidea yesoensis

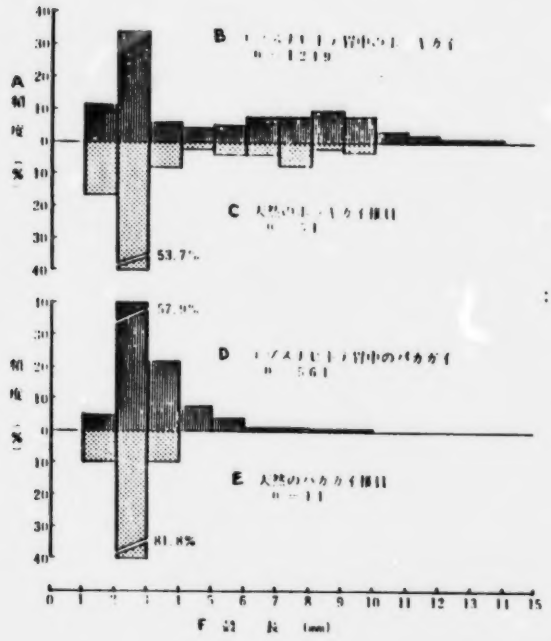
Key: A. Pseudocardium sybillae, B. Mactra chinensis, C. Number of individuals eaten per individual Luidea yesoensis, D. Individuals, - indicates a survey point at which Luidea yesoensis were not found.



第6図 ホッキガイ稚貝とバカガイ稚貝の分布

Fig. 6: Distribution of Juvenile Pseudocardium sybillae and Juvenile Mactra chinensis

Key: A. Pseudocardium sybillae, B. Mactra chinensis, C. Individuals/m^2.



n は測定個体数

第7図 エゾスナヒトデに捕食されたものと天然のホッキガイ稚貝とバカガイ稚貝の殻長組成

Fig. 7: Breakdown by Shell Length of Juvenile Pseudocardium sybillae and Juvenile Mactra chinensis Eaten by Luidea yesoensis and of Those Found in Their Natural Habitat

Key:

A. Frequency (%), B. Pseudocardium sybillae in the stomach of Luidea yesoensis, C. Juvenile Pseudocardium sybillae found in their natural habitat, D. Mactra chinensis in the stomach of Luidea yesoensis, E. Juvenile Mactra chinensis found in their natural habitat, F. Shell length (mm), n. Number of individuals measured.

Table 1: Density and Percentage Breakdown of Sea Stars

第1表 ヒトデ類の密度と構組比率

A ヒトデの種類	F 野付半島漁場		G 竜神堆漁場	
	H 密度(個体/m²)	構組比率(%) I	密度(個体/m²)	構組比率(%)
B ヒトデ	0.238	59.9	0.110	65.4
C エゾスナヒトデ	0.136	34.3	0.052	31.0
D ニッポンヒトデ	0.012	3.0	0.003	1.8
E イトマキヒトデ	0.011	2.8	0.003	1.8

Key:

A. Species of sea stars, B. Asterias amurensis, C. Luidea yesoensis, D. Distolasterias nippon, E. Asterina pectinifera, F. Notsuke Peninsula fishing ground, G. Ryūjin Bank fishing ground, H. Density (individuals/m^2), I. Percentage breakdown.

Table 2: Stomach Contents of Sea Stars

第2表 ヒトデ類の胃内容物

A 胃内に出現する動物	B 捕食個体数*			
	C ヒトデ	D ニッポンヒトデ	E エゾスナヒトデ	F イトマキヒトデ
G ホッキガイ	0.315		4.760	
H バカガイ	0.105	0.125	4.711	
I オオミゾガイ			0.103	
J フリソデガイ			0.015	
K オオキララガイ		0.125		
L ビノスガイ			+	
M オオノガイ			+	
N ケショウシラトリガイ			+	
O エゾイソシジミ			+	
P ノミハマグリ			+	
Q 他の二枚貝類			0.037	
R チシマタマガイ			+	
S タマツメタガイ			+	
T ハデクチキレ		0.125	+	
U 他の巻貝類		0.125	0.020	
V シオムシ	0.789	0.625	0.128	0.666
W ヨコエビ類			0.017	
X ワレカラ類			+	
Y クマ類	0.052		+	
Z エビジャコ	0.105			
AA 長尾類	0.105		+	0.166
BB クリガニ			+	
CC 短尾類			0.027	
DD ハイイロハスノハカシパン			+	
EE ホヤ類			+	
FF 多毛類			0.012	
GG ヒモ形類			+	

*ヒトデ類の捕食個体数は、胃内容物を観察したヒトデ類のうち空胃個体を除くヒトデ類1個体あたりの平均捕食個体数。0.001未満は切り捨て、+は0.001未満の頻度で出現したことを示す。

*The number of individuals eaten by sea stars is the average number of individuals eaten per sea star among the sea stars whose stomach contents were observed, excluding individuals with an empty stomach. Cases in which the figure was less than 0.001 were omitted, and + indicates cases in which the animal was found at a frequency less than 0.001.

Key:
A. Animals found in stomach, B. Number of individuals eaten*, C. Asterias amurensis, D. Distolasterias nippon, E. Luidea yesoensis, F. Asterina pectinifera, G. Pseudocardium sybillae, H. Mactra chinensis, L. Siliqua alta (Broderip et Sowerby), J. Yoldia (Cnesterium) notabilis Yokoyama, K. Acila divaricata (Hinds), L. Mercenaria stimpsoni (Gould), M. Mya (Arenomya) arenaria (?) oonogai Makiyama, N. Keshōshiratorigai**, O. Ezoisoshijimi**, P. Nomihamaguri**, Q. Other bivalves, R. Chishimatamagai**, S. Tamatsumetagai**,

**Transliteration of Japanese name. Search for Latin name unsuccessful.

T. Hadekuchikire **, U. Other spiral-shelled molluscs, V. Shiomushi**, W. Yokoebi**-like animals, X. Skeleton shrimp, Y. Kuma**-like animals, Z. Ebijako**, AA. Marcura, BB. Kurigani**, CC. Brachyura, DD. Scaphechinus mirabilis (A. Agassiz), EE. Ascidians, FF. Polychaeta, GG. Nemertea.

**Transliteration of Japanese name. Search for Latin name unsuccessful.